# Energy Conservation Standards for Commercial Unitary Air Conditioners and Heat Pumps

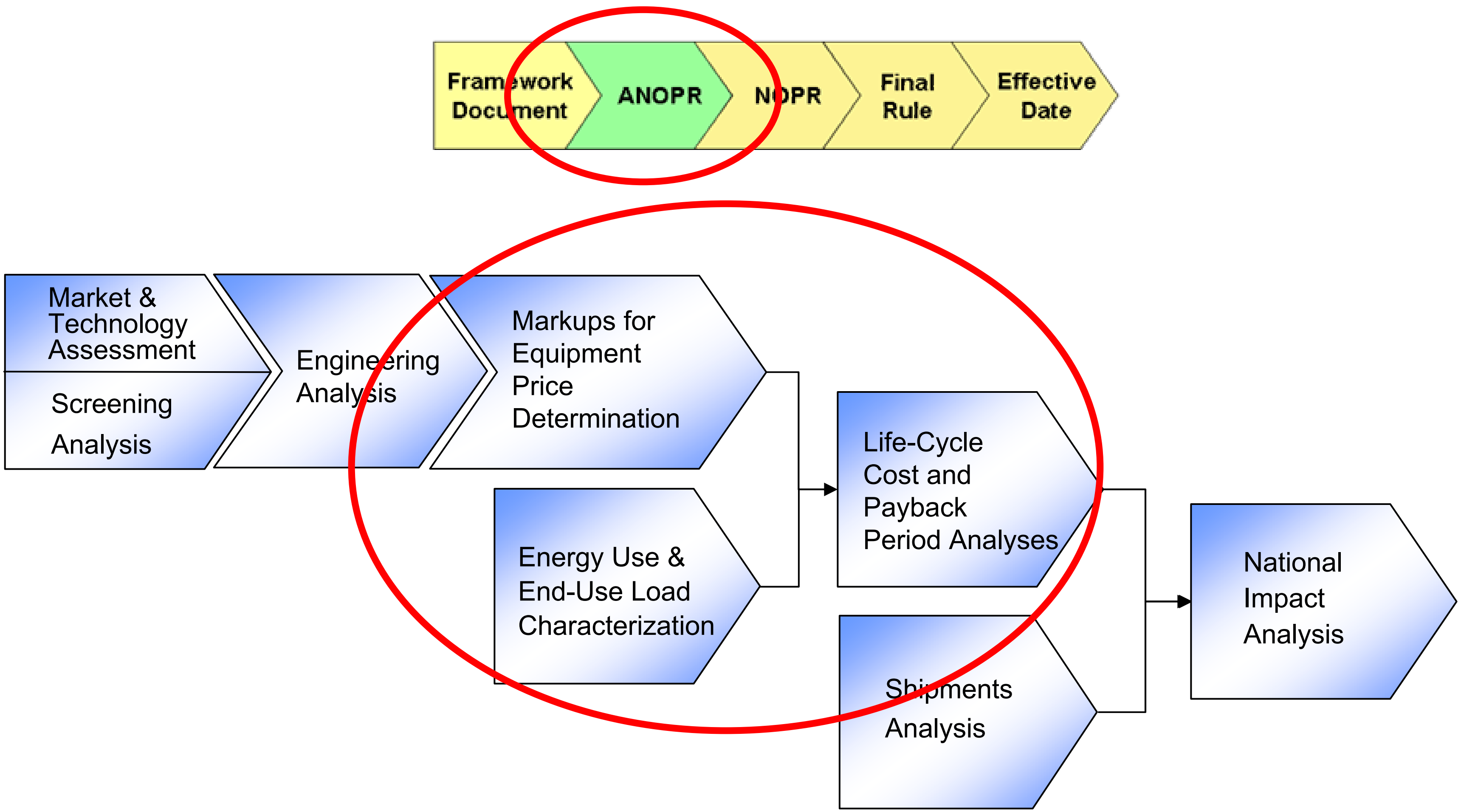
## ANOPR Public Meeting

# Life-Cycle Cost Analysis

Building Technologies Program
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

September 30, 2004

# ANOPR Analyses Flow Diagram



# Purpose

- **Energy Use & End-Use Load Characterization**
  - To develop electrical energy use and peak electrical demand characteristics for buildings that use commercial unitary air-conditioning equipment.
  - To provide these characteristics for selected equipment efficiency levels across a diverse set of commercial buildings and climates.

- **Markups for Equipment Price Determination**
  - To characterize the channels for how equipment is distributed from the manufacturer to the customer.
  - To determine prices paid by customers based on manufacturer prices of base case and higher efficiency equipment.

- **Life-Cycle Cost and Payback Period Analyses**
  - To develop the customer life-cycle cost savings and payback periods of higher efficiency equipment.

# ANOPR Issues for Public Comment

- Building Sample (ANOPR Issue #16a)
- Economizer Performance (ANOPR Issue #6)
- Fan Energy Consumption (ANOPR Issue #7 and Issue #16c)
- BLAST and CBECS Estimates of Energy Use (ANOPR Issue #16b)
- Equipment Markups (ANOPR Issue #8 and Issue #16d)
- Exclusion of Light Industrial Buildings (ANOPR Issue #5)
- Hourly Based Electricity Prices (ANOPR Issue #9)
- Forecasts of Electricity Prices (ANOPR Issue #10)
- Equipment Lifetime (ANOPR Issue #11)
- Effect of Income Taxes on LCC (ANOPR Issue #17)
- Rebound Effect (ANOPR Issue #20)

# The Need for Building Simulation

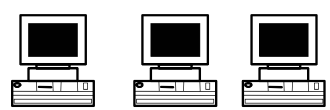
- **Lack of an available data source providing a broad characterization of cooling loads and their contribution to electrical loads profiles in commercial buildings**
- **A need to capture diversity of cooling loads across different building types and climate zones**
- **A need to characterize hourly and peak building electrical loads for use in the LCC analysis**

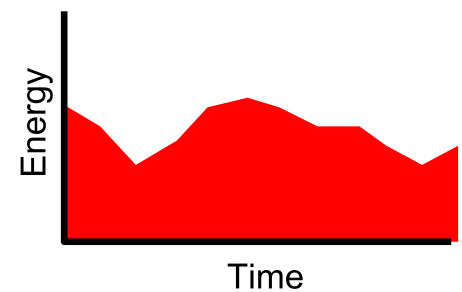
# Simulation Overview

Characterization of Building Stock Using CBECS[1] Data

Development and Simulation of Building Prototypes Using BLAST[2]

Hourly Whole-Building Energy End Use Profiles






[1] CBECS: *Commercial Building Energy Consumption Survey* conducted by DOE's Energy Information Administration (EIA)

2 BLAST: *Building Loads and System Thermodynamics* energy simulation tool

# Simulation Methodology

15-zone, 3-story Prototype (48,000 sf)

Size equipment with BLAST design-day run

Simulate annual energy use with BLAST

Scale results to match actual building geometry

CBECS – inferred size and geometry

Adjust cooling and fan energy use for less than 100% packaged cooling

# Data Source for Key Simulation Inputs

| Data Source | Simulation Inputs |
| --- | --- |
| Direct from CBECS | Building type, floor area, number of floors, wall construction, roof type, occupancy density, economizer use, use of temperature setback |
| Inferred from CBECS | Typical Meteorological Year (TMY2) station for weather data<br><br>Window wall ratio (WWR)*, building aspect ratio*, building use schedules |
| Derived from Other Sources | Lighting power density, equipment power density, occupancy density (where not available in CBECS), infiltration, peak ventilation, Energy Efficiency Ratio (EER), system over-sizing factor* |

*Values for **WWR, aspect ratio, and system over-sizing factor** were chosen randomly from population distributions developed for these input variables

# Simulation Output

- **Each of the 1033 buildings was simulated for each of the 10 efficiency levels. The results provided from this analysis are:**
  - A stream of hourly electrical consumption data for each building end-use (including cooling)
  - The number of 7.5 ton or 15 ton air-conditioning units that would be installed in the building to meet the peak loads

# Building Sample
# (ANOPR Issue #16a)

A sample of 1033 buildings selected from CBECS was simulated to develop the energy use characteristics for this analysis.

This sample consists of six building types: assembly, education, food services, office, retail and non-refrigerated warehouse.

This sample represents approximately 70% of the floor space cooled by packaged air-conditioning equipment in CBECS.

**The Department seeks comments on the building sample selection process.**

# Economizer Performance
# (ANOPR Issue #6)

Where economizer usage was indicated by CBECS in a particular building, the simulation assumed economizers were used.

Where economizer usage was indicated by CBECS, the simulations assumed that economizers operated flawlessly and with an enthalpy control strategy, maximizing benefits.

**The Department seeks comments on the economizer usage, control strategy, and performance assumptions.**

# Fan Energy Consumption (ANOPR Issue #7 and Issue #16c)

The fans used in unitary air conditioners and heat pumps typically provide for ventilation during all building operating hours (cooling, heating and purely ventilating modes). This assumption was used in the simulation. Thus energy savings from reductions in supply fan power accrue during all hours of building operation.

**The Department seeks comments on the fan power and modeling assumptions.**

# BLAST and CBECS Estimates of Energy Use (ANOPR Issue #16b)

The average simulated cooling energy use from BLAST simulations only slightly exceeded the reported CBECS cooling energy for the building sample (developed through a separate modeling process). There is, however, significant variation between the BLAST and CBECS cooling energy use for any individual building.

**The Department seeks comments on the value of comparing the average simulated cooling energy use with the CBECS-modeled results.**

**The Department seeks comments on the characterization of the building energy use and end use loads.**

# Purpose, Inputs, and Output

## Purpose

- To determine customer prices based on manufacturer costs
- Characterize distribution channels and market segments
- Analyze company direct costs, expenses, and profits

## Inputs

- Firm balance sheets
  - Wholesalers: ARW *1998 Wholesaler PROFIT Survey Report for Wholesalers*
  - Mechanical Contractors: ACCA *1995 Financial Analysis for the HVACR Contracting Industry*
- U.S. Census Bureau data
  - General Contractors: *1997 Economic Census of Commercial and Industrial Building Construction*

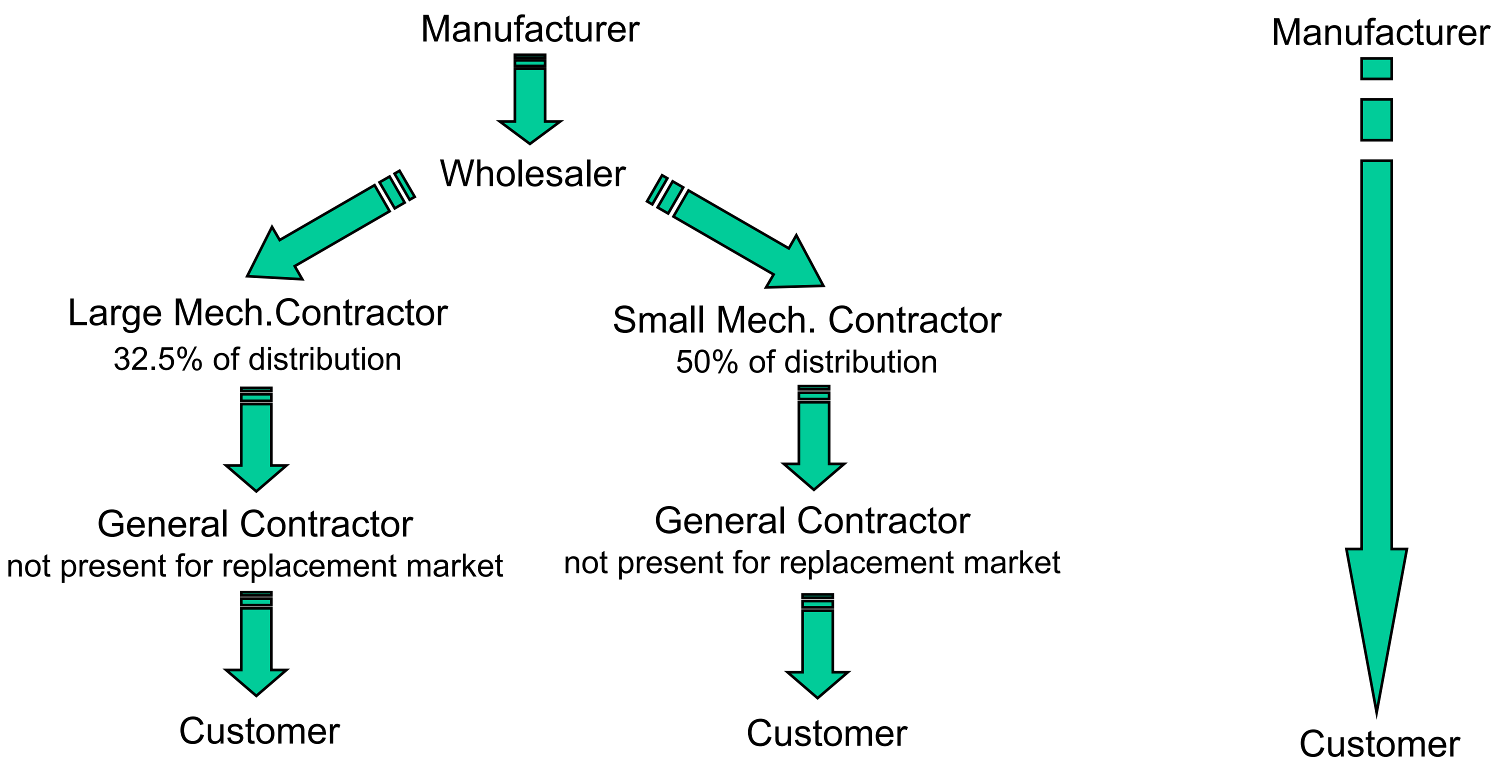
## Output

- Baseline and incremental markups

# Distribution Channels

**Distribution Channels 1 & 2**
represents 82.5% of distribution

**Distribution Channel 3 (Nat'l Acct)**
represents 17.5% of distribution




- Two construction types: Replacement (70%) and New Construction (30%)

# Baseline and Incremental Markups

- ***Markups* relate customer price to cost of goods sold (COGS)**
- ***Baseline markups* relate price to cost prior to a change in efficiency**
  - Baseline markups indicate a customer price that covers all of a wholesaler's or contractor's expenses plus profit
  - Direct labor costs (salaries, payroll, rental and occupancy) are included
- ***Incremental markups* relate the incremental change in customer price to the incremental change in COGS**
  - Some costs remain constant with COGS increases
  - Incremental markups cover only expenses that vary with COGS – in this case, expenses that increase due to an increase in equipment efficiency
  - For example, direct labor costs (salaries, payroll, rental and occupancy) do not vary with efficiency-induced changes in COGS Labor Expenses

# Example of Markup Results

## New Construction - Range and Average Markup Values

| | Baseline | | Incremental | |
|---|---|---|---|---|
| | Range | Average | Range | Average |
| Wholesaler | 1.02 – 1.70 | 1.36 | 1.00 – 1.22 | 1.11 |
| Large Mechanical Contractor | 1.22 – 1.47 | 1.35 | 1.08 – 1.29 | 1.18 |
| Small Mechanical Contractor | 1.34 – 1.61 | 1.48 | 1.14 – 1.37 | 1.26 |
| General Contractor | 1.10 – 1.38 | 1.24 | 1.00 – 1.26 | 1.13 |
| Sales Tax | 1.00 – 1.10 | 1.07 | 1.00 – 1.10 | 1.07 |

## Replacement Market - Range and Average Markup Values

| | Baseline | | Incremental | |
|---|---|---|---|---|
| | Range | Average | Range | Average |
| Wholesaler | 1.02 – 1.70 | 1.36 | 1.00 – 1.22 | 1.11 |
| Large Mechanical Contractor | 1.41 – 1.69 | 1.55 | 1.08 – 1.29 | 1.29 |
| Small Mechanical Contractor | 1.54 – 1.86 | 1.70 | 1.17 – 1.41 | 1.37 |
| Sales Tax | 1.00 – 1.10 | 1.07 | 1.00 – 1.10 | 1.07 |

| | Baseline Average | Incremental Average |
|---|---|---|
| National Account | 1.60 | 1.24 |

| | Baseline Weighted-Average | Incremental Weighted-Average |
|---|---|---|
| OVERALL MARKUPS | 2.31 | 1.56 |

# Equipment Markups
# (ANOPR Issue #8 and Issue #16d)

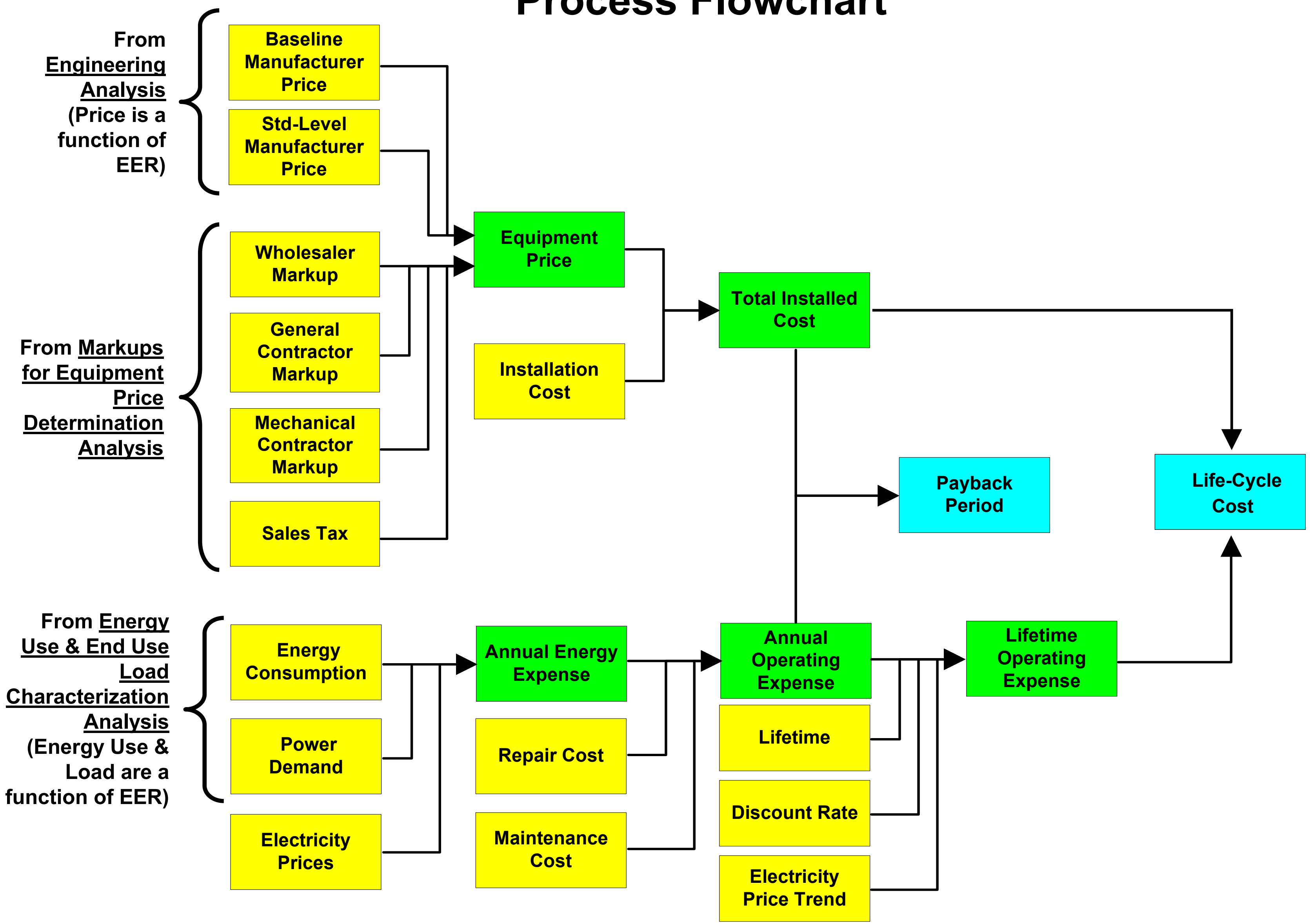
Baseline and incremental markups were developed for wholesalers, mechanical contractors, and general contractors to transform manufacturer prices into customer prices.

Incremental markups cover only those expenses associated with a *change* in manufacturer price. For example, because direct labor expenses do not change with an increase in the manufacturer price (such as office salaries), they are *not* covered by incremental markups.

Because fewer expenses are covered, the incremental markup has a lower value than the baseline markup.

**The Department seeks comments on the type of wholesaler, mechanical contractor, and general contractor expenses that need to be covered by the incremental markup.**

# Process Flowchart



# Tariff-based and Hourly based Electricity Prices

- **Tariff-based approach**
  - Primary approach for developing electricity prices
  - Based on non-residential electric utility tariffs collected in 2001
- **Hourly based approach**
  - Secondary approach for developing electricity prices
  - Based on a scenario in which customers are directly charged for the costs incurred by an electricity provider to supply energy for air-conditioning
    - Based on wholesale cost and utility system lambda data
  - Prices that may exist assuming all electricity markets are deregulated
- **Marginal prices are developed from both approaches**
  - Tariffs and hourly costs are applied to building energy use and demand data
  - Electricity bill savings and marginal prices calculated from an efficiency improvement to air-conditioning equipment
  - National average marginal commercial prices are 10 ¢/kWh

# Electricity Price Results

- **National average tariff-based and hourly based marginal prices are virtually the same**
  - Tariff-based and hourly based prices vary regionally
  - Large component of marginal price is due to demand

| No. | Subdivision | States | Unit Weighting | Tariff-based Marginal Price | | Hourly based Marginal Price | |
|---|---|---|---|---|---|---|---|
| | | | | Cents/kWh | % demand | Cents/kWh | % capacity |
| 1 | New England | CT,MA,ME,NH,RI,VT | 4.7 | 9.5 | 53% | 10.7 | 43% |
| 2.1 | New York | NY | 7.4 | 14.6 | 53% | 10.5 | 35% |
| 2.2 | Mid Atlantic | NJ,PA | 5.6 | 10.5 | 27% | 8.7 | 48% |
| 3 | EN Central | IL,IN,MI,OH,WI | 13.7 | 10.8 | 46% | 11.0 | 65% |
| 4.1 | W-WN Central | KS,ND,NE,SD | 0.8 | 6.2 | 44% | 8.4 | 60% |
| 4.2 | E-WN Central | IA,MO,MN | 4.7 | 7.1 | 30% | 9.8 | 60% |
| 5.1 | N-S Atlantic | DE,MD,VA,WV | 5.6 | 7.9 | 41% | 9.9 | 63% |
| 5.2 | Mid-S Atlantic | GA,NC,SC | 7.9 | 7.3 | 22% | 7.4 | 68% |
| 5.3 | Florida | FL | 6.6 | 8.0 | 36% | 11.0 | 66% |
| 6.1 | N-ES Central | KY,TN | 5.1 | 6.5 | 38% | 8.0 | 68% |
| 6.2 | S-ES Central | AL,MS | 5.4 | 6.1 | 39% | 12.8 | 70% |
| 7.1 | N-WS Central | AR,LA,OK | 5.3 | 5.8 | 26% | 11.6 | 76% |
| 7.2 | Texas | TX | 9.5 | 10.0 | 23% | 10.8 | 75% |
| 8.1 | N-Mountain | ID,MT,WY | 0.6 | 6.1 | 20% | 4.5 | 43% |
| 8.2 | S-Mountain | AZ,CO,NM,NV,UT | 4.2 | 8.8 | 35% | 9.5 | 69% |
| 9.1 | N-Pacific | OR,WA | 1.7 | 4.5 | 33% | 5.4 | 24% |
| 9.2 | California | CA | 11.2 | 18.5 | 21% | 8.5 | 46% |
| | **USA** | | 100.0 | **10.0** | **35%** | **9.9** | **60%** |

# Exclusion of Light Industrial Buildings (ANOPR Issue #5)

Building simulations were performed on commercial buildings with commercial unitary air conditioners in order to generate electrical loads. Electrical loads were coupled with electricity prices (either tariff based or hourly based) to generate customer utility bills.

Light industrial buildings were not analyzed due to insufficient data.

By not analyzing industrial buildings, the LCC analysis implicitly assumes that the electrical loads and electricity prices in light industrial buildings are not substantially different than those in commercial buildings.

**The Department seeks comments on whether light industrial buildings have substantially different electrical loads and electricity prices from commercial buildings.**

**If light industrial buildings have substantially different loads and prices, the Department seeks comments on whether there are significant commercial unitary air conditioner shipments to these buildings to warrant their inclusion into the analysis.**

# Hourly Based Electricity Prices (ANOPR Issue #9)

Hourly based prices were used as a secondary approach to establish marginal electricity prices. Tariff-based prices were the primary approach.

Extensive data were used to characterize hourly costs. Hourly wholesale cost data were collected from deregulated regions of the country and hourly system lambda data were collected from regulated regions.

Hourly cost data were input into a customer price model to compute annual utility bills. The price model was based on avoided-cost methodologies traditionally used by utilities to characterize demand reduction programs.

**The Department seeks comments on other price models for calculating annual utility bills from hourly cost data.**

**The Department seeks comments on the use of hourly based prices as a secondary approach for developing marginal prices.**

# Other Inputs

- **Installation Costs**
  - Based on RS Means data: $1585 for baseline 7.5 ton unit, $2142 for 15 ton unit
  - Costs vary in direct proportion to equipment weight
- **Electricity Price Forecasts**
  - Based upon trends from the *2003 Annual Energy Outlook*
- **Discount Rates**
  - Derived from estimates of the cost of capital of companies that purchase unitary a/c
  - Cost of capital is calculated from the weighted-average cost of capital to the firm (WACC) to obtain equity and debt financing
  - Weighted-average value equals 6.1% real
- **Equipment Lifetime**
  - Median age of 15 years based upon *1999 ASHRAE HVAC Applications Handbook*
  - Survival function based upon Weibull probability distribution
- **Repair Costs**
  - Baseline annual repair cost: $158 for 7.5 ton unit, $291 for 15 ton unit
  - Increases in direct proportion to equipment manufacturing price
- **Maintenance Costs**
  - Based on RS Means data for 3 to 24 ton roof top air conditioners
  - Annual maintenance cost equals $200 and does not vary with capacity or efficiency

# Forecasts of Electricity Prices (ANOPR Issue #10)

Electricity price forecasts from the *2003 Annual Energy Outlook* were used to estimate future electricity prices.

The Department plans on using the most recent *Annual Energy Outlook* available in its analyses for the NOPR.

**The Department seeks comments on any other credible electricity price forecasts.**

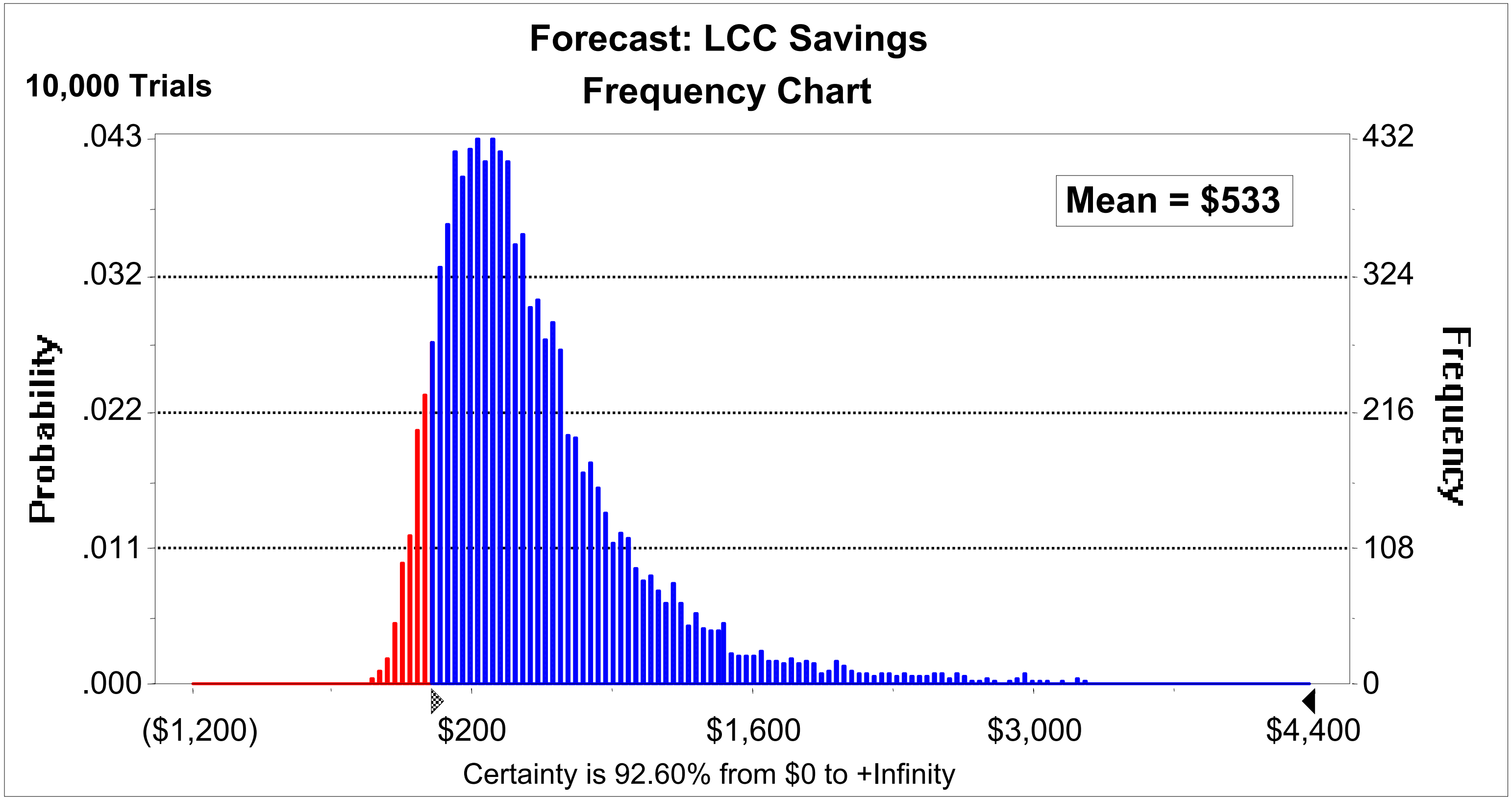
# Equipment Lifetime
# (ANOPR Issue #11)

Based on the *1999 ASHRAE HVAC Applications Handbook*, the Department used a value of 15 years as the median lifetime of commercial unitary air conditioners.

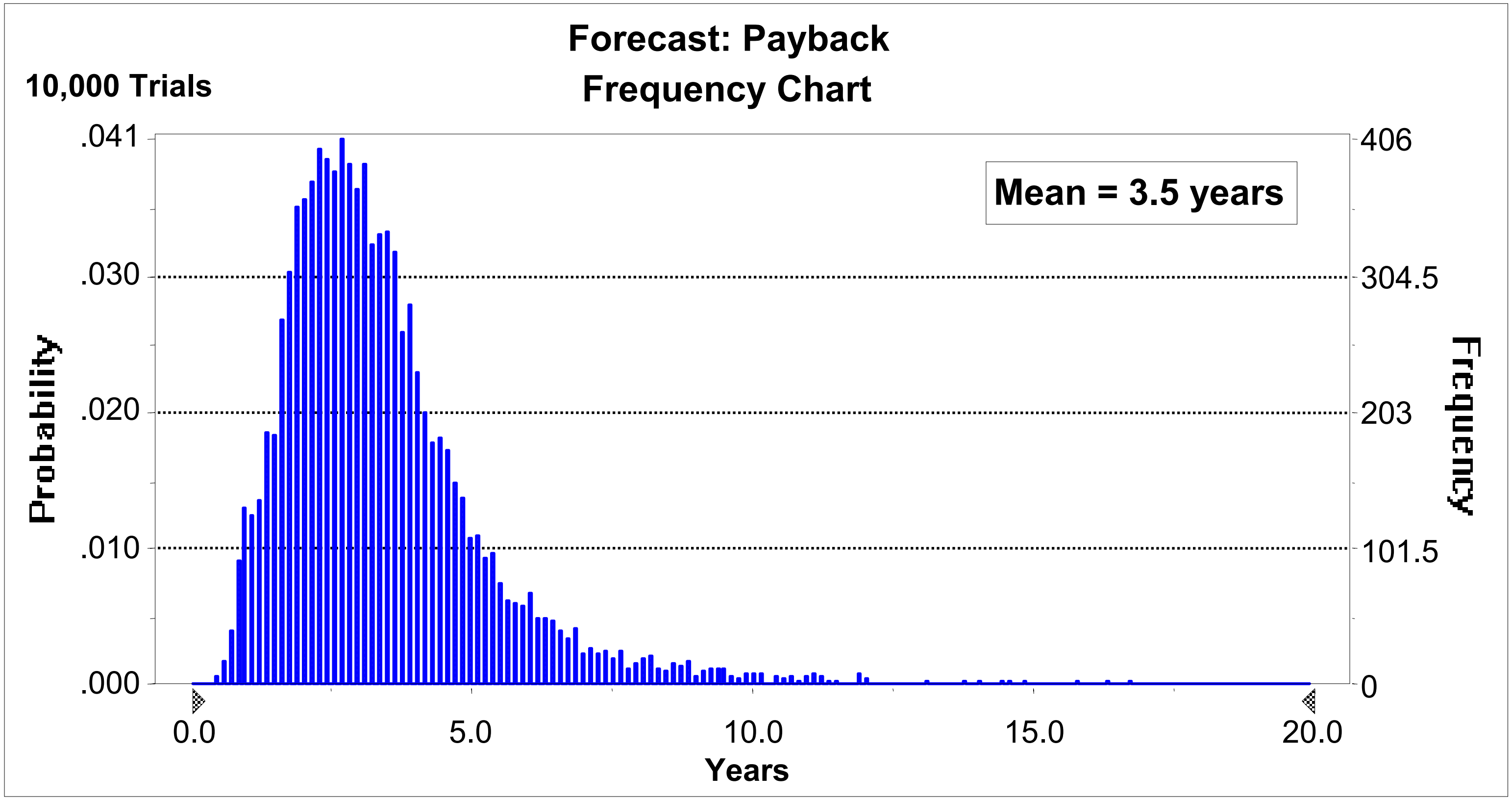
A Weibull probability distribution with a median value of 15 years was used to characterize the survival function for commercial unitary air conditioners.

**The Department seeks comments on the lifetime of commercial unitary air conditioners.**

# Example of LCC Results: 7.5 ton (≥65,000 Btu/h and <135,000 Btu/h), 11.0 EER



# Example of Payback Period Results: 7.5 ton (≥65,000 Btu/h and <135,000 Btu/h), 11.0 EER



# Effect of Income Taxes on LCC (ANOPR Issue #17)

The Department did not include the effect of income taxes in the LCC analysis for this ANOPR.

The Department believes the net impact of taxes on the LCC analysis depends upon how a firm's accounting procedures expense the purchase cost of commercial equipment and measure profitability.

**For firms that purchase commercial unitary air conditioning equipment, the Department seeks comments on the number of firms which face a net tax liability.**

**For those firms with a net tax liability, the Department seeks comments on how equipment is expensed and depreciated over time.**

# Rebound Effect
# (ANOPR Issue #20)

The rebound effect occurs when a piece of equipment that is made more efficient is used more intensively, so that the expected energy savings from the efficiency improvement do not fully materialize.

The rebound effect was not taken into account when estimating the energy savings from more efficient equipment.

**The Department seeks comments on the presence of a rebound effect for commercial unitary air conditioner customers.**

**If a rebound effect does exist, the Department seeks data for basing the calculation of the rebound effect.**

# Other Issues

**The Department seeks comments and recommendations from stakeholders on any other aspects related to the Life-Cycle Cost Analysis.**